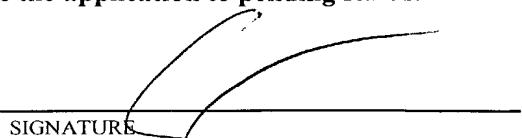


FORM PTO-1390 (REV 10-95)		U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY'S DOCKET NUMBER
<b>TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. §371</b>		<b>DCLERC 1</b>	
INTERNATIONAL APPLICATION NO <b>PCT/EP00/04632</b>		INTERNATIONAL FILING DATE <b>22 MAY 2000</b>	U S APPLICATION NO (If known, see 37 CFR §1.5) <b>10/049284</b>
		PRIORITY DATE CLAIMED <b>11 AUGUST 1999</b>	
TITLE OF INVENTION <b>METHODS FOR PREPARING PERFLUORINATED [<sup>18</sup>F]-RADIOLABELLED NITROIMIDAZOLE DERIVATIVES FOR CELLULAR HYPOXIA DETECTION</b>			
APPLICANT(S) FOR DO/EO/US <b>MARCHAND, Jacqueline, et al</b>			
<p><b>Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:</b></p> <ol style="list-style-type: none"> <li>1. <input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. §371.</li> <li>2. <input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. §371</li> <li>3. <input type="checkbox"/> This express request to begin national examination procedures (35 U.S.C. §371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. §371(b) and PCT Articles 22 and 39(1).</li> <li>4. <input checked="" type="checkbox"/> A proper Demand for International Preliminary Examination was made by the 19<sup>th</sup> month from the earliest claimed priority date.</li> <li>5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. §371(c)(2)) <ul style="list-style-type: none"> <li>a. <input type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau).</li> <li>b. <input checked="" type="checkbox"/> has been transmitted by the International Bureau.</li> <li>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).</li> </ul> </li> <li>6. <input type="checkbox"/> A translation of the International Application into English (35 U.S.C. §371(c)(2)).</li> <li>7. <input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. §371(c)(3)) <ul style="list-style-type: none"> <li>a. <input type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau)</li> <li>b. <input type="checkbox"/> have been transmitted by the International Bureau.</li> <li>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</li> <li>d. <input checked="" type="checkbox"/> have not been made and will not be made.</li> </ul> </li> <li>8. <input type="checkbox"/> A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. §371(c)(3)).</li> <li>9. <input type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. §371(c)(4)).</li> <li>10. <input type="checkbox"/> A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. §371(c)(5)).</li> </ol> <p><b>Items 11. to 16. below concern document(s) or information included:</b></p> <ol style="list-style-type: none"> <li>11. <input type="checkbox"/> An Information Disclosure Statement under 37 C.F.R. §§1.97 and 1.98</li> <li>12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 C.F.R. §§3.28 and 3.31 is included.</li> <li>13. <input checked="" type="checkbox"/> A <b>FIRST</b> preliminary amendment.</li> <li>14. <input type="checkbox"/> A <b>SECOND</b> or <b>SUBSEQUENT</b> preliminary amendment.</li> <li>15. <input type="checkbox"/> A substitute specification.</li> <li>16. <input type="checkbox"/> A change of power of attorney and/or address letter.</li> <li>17. <input type="checkbox"/> Other items or information:</li> </ol>			

U.S. APPLICATION NO. (if known, see 37 CFR §1.5) <b>10/049284</b>		INTERNATIONAL APPLICATION NO <b>PCT/EP00/04632</b>	ATTORNEY'S DOCKET NUMBER <b>DCLERC-1</b>	
17. <input checked="" type="checkbox"/> The following fees are submitted:		<b>CALCULATIONS</b> PTO USE ONLY		
<b>BASIC NATIONAL FEE (37 CFR §1.492 (a) (1) - (5)):</b>				
Search Report has been prepared by the EPO or JPO.....		\$890.00		
International preliminary examination fee paid to USPTO (37 CFR §1.482). ....		\$710.00		
No international preliminary examination fee paid to USPTO (37 CFR §1.482) but international search fee paid to USPTO (37 CFR §1.445(a)(2)) ....		\$740.00		
Neither international preliminary examination fee (37 CFR §1.482) nor international search fee (37 CFR §1.445(a)(2)) paid to USPTO.....		\$1040.00		
International preliminary examination fee paid to USPTO (37 CFR §1.482) and all claims satisfied provisions of PCT Article 33(2)-(4).....		\$100.00		
<b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>		<b>\$890.00</b>		
Surcharge of <b>\$130.00</b> for furnishing the oath or declaration later than months from the earliest claimed priority date (37 C.F.R. §1.492(e)).		<input type="checkbox"/> 20	<input type="checkbox"/> 30	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	
Total claims	30 - 20 =	10	x \$ 18.00	<b>\$180.00</b>
Independent claims	3 - 3 =	0	x \$ 84.00	<b>\$0.00</b>
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ \$ 280.00	
<b>TOTAL OF ABOVE CALCULATIONS =</b>		<b>\$1,070.00</b>		
Reduction of 1/2 for filing by small entity, if applicable. A Verified Small Entity Statement must also be				
<b>SUBTOTAL =</b>		<b>\$1,070.00</b>		
Processing fee of <b>\$130.00</b> for furnishing the English translation later than months from the earliest claimed priority date (37 C.F.R. §1.492(f)).		<input type="checkbox"/> 20	<input type="checkbox"/> 30	
<b>TOTAL NATIONAL FEE =</b>		<b>\$1,070.00</b>		
Fee for recording the enclosed assignment (37 C.F.R. §1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 C.F.R. §§3.28, 3.31). \$40.00 per property.				
<b>TOTAL FEES ENCLOSED =</b>		<b>\$1,070.00</b>		
		Amount to be refunded:		
		charged:		
a. <input checked="" type="checkbox"/> A check in the amount of <u>\$1,070.00</u> to cover the above fees is enclosed.				
b. <input type="checkbox"/> Please charge my Deposit Account No. <u>13-3402</u> in the amount of <u>\$</u> to cover the above fees. A duplicate copy of this sheet is enclosed.				
c. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>13-3402</u> . A duplicate copy of this sheet is enclosed.				
<b>NOTE: Where an appropriate time limit under 37 C.F.R. §§1.494 or 1.495 has not been met, a petition to revive (37 C.F.R. §1.137(a) or (b)) must be filed and granted to restore the application to pending status.</b>				
SEND ALL CORRESPONDENCE TO Customer Number 23,599				
 <b>23599</b> PATENT TRADEMARK OFFICE				
 <b>Anthony J. Zelano</b> NAME <b>27,969</b> REGISTRATION NUMBER				
Filed: 11 February 2002 AJZ:kmo				

**IN THE UNITED STATES DESIGNATED/ELECTED OFFICE**

International Application No. : PCT/EP00/04632  
International Filing Date : 22 MAY 2000  
Priority Date(s) Claimed : 11 AUGUST 1999  
Applicant(s) (DO/EO/US) : MARCHAND, Jacqueline, et al.

Title: METHODS FOR PREPARING PERFLUORINATED [<sup>18</sup> F ]-RADIOLABELLED NITROIMIDAZOLE DERIVATIVES FOR CELLULAR HYPOXIA DETECTION

**PRELIMINARY AMENDMENT**

Commissioner for Patents  
Washington, D.C. 20231

SIR:

Prior to calculating the national fee, and prior to examination in the National Phase of the above-identified International application, please amend as follows:

**IN THE CLAIMS:**

1. (Amended) A compound according to claim 1 having the formula 2(2-nitro-1H-imidazol-1-yl)-N-(3,3,3-trifluoropropyl) acetamide ([<sup>18</sup>F]-EF2).
2. (Amended) A compound according to claim 1 having the formula 2(2-nitro-1H-imidazol-1-yl)-N-(2,2,3,3,3-pentafluoropropyl) acetamide ([<sup>18</sup>F]-EF5).
3. (Amended) A method for the synthesis of a compound according to claim 1, comprising the step of coupling 2-(2-nitro-imidazol-1-yl) acetic acid with a [<sup>18</sup>F]-labeled perfluoroalkyl amine derivative.

7. (Amended) A method for the synthesis of a compound according to claim 1 or the corresponding non-labeled form thereof, comprising the steps of:

- a) adding a THF solution of 2 of Figure 7 to a suspension of PYBOP in THF followed by Et<sub>3</sub>N,
- b) adding an amine 1 of Figure 7 and Et<sub>3</sub>N to the solution obtained in step (a),
- c) adding a catalytic amount to the solution obtained in step (b) of pTsOH and refluxing the solution,
- d) cooling the solution obtained after step (c) at ambient temperature and adding a sodium bicarbonate solution,
- e) extracting the product obtained after step (d) with ethyl acetate and drying and concentrating the product with ethyl acetate,
- f) purifying the residue obtained after step (e) by column chromatography on silica gel,
- g) removing traces of water by washing the product of step (f) with trifluoroacetic anhydride,
- h) reacting said persulphurated derivative obtained from step (g) with a suitable labelled or non-labelled perfluorinating agent and a suitable oxidant resulting in a compound having a high yield of fluor atom incorporation,
- i) deprotecting the nitrogen function, resulting in a perfluoroalkyl amine derivative, and
- j) coupling the perfluoroalkyl amine derivative obtained in step (i) with an activated form of 2-(2-nitro-imidazol-1-yl) acetic acid, resulting in the [<sup>18</sup>F]-labelled or non-labelled perfluorinated-nitroaromatic compound.

9. (Amended) A [<sup>18</sup>F]-labeled compound obtainable by a method according to claim 5.

12. (Amended) A first intermediate compound according to claim 10, obtainable via steps a to g of the method of the invention.

13. (Amended) A first intermediate compound according to claim 10, being ethyl 3-(N-phthalimido)-aminopropanedithioate, N-3,3,3-trifluoro-2-thioxopropyl) phthalimide, N-{{[2-(trifluoromethyl)-1,3-dithiolan-2-yl] methyl} phthalimide, methyl(or ethyl) 3-phthalimide-2,2-difluoropropanedithioate, N-[2,2-difluoro-3,3,3-tris(methylthio) propyl] phthalimide or N-[2,2-difluoro-3,3,3-tris(ethylthio)propyl] phthalimide.

16. (Amended) A second intermediate compound according to claim 14, obtainable via steps a to h of the method of the invention.

17. (Amended) A second intermediate compound according to claim 14, being N-(3,3,3-trifluoropropyl)phthalimide.

20. (Amended) A third intermediate [<sup>18</sup>F]-labeled compound obtainable via steps a to i of the method of the invention.

21. (Amended) Use of compound according to claim 1 as bioactive compound.

22. (Amended) A [<sup>18</sup>F] labeled bioactive compound synthesized using as intermediates a first and third intermediate as claimed in claim 10, a second intermediate having the general formula of a [<sup>18</sup>F]-labeled perfluorinated amino acid derivative which is N-protected by an imido group or a synthetically equivalent group.

23. (Amended) A [<sup>18</sup> F] labeled bioactive compound synthesized using as intermediates a first intermediate as claimed in claim 10.

24. (Amended) Method of perfuorination using as an intermediate a compound as claimed in claim 10.

26. (Amended) A method for the detection of tissue hypoxia in a patient comprising:  
- introducing an [<sup>18</sup>F] labeled nitroimidazole compound of claim 1 into said patient,  
- imaging tissue hypoxia in said patient, and  
- quantifying tissue hypoxia in said patient.

28. (Amended) A method for the detection of tissue hypoxia in a tissue comprising:  
- introducing an [<sup>18</sup>F] labeled nitroimidazole compound of claim 1 into a patient,  
- removing a tissue sample from said patient, and  
- analysing the emission in said tissue sample by autoradiography.

29. (Amended) A method for the detection of an [<sup>18</sup>F] labeled bioactive compound in a patient comprising:  
- introducing an [<sup>18</sup>F] labeled bioactive compound according to claim 1 into said patient,  
- imaging the presence of said [<sup>18</sup>F] labeled bioactive compound in said patient, and  
- optionally, quantifying the presence of said [<sup>18</sup>F] labeled bioactive compound in said patient.

30. (Amended) A method for the detection of [<sup>18</sup>F] labeled bioactive compound in a tissue comprising:  
- introducing an [<sup>18</sup>F] labeled bioactive compound of claim 1 into a patient,  
- taking a tissue sample from said patient, and  
- analysing the emission in said tissue sample by autoradiography.

REMARKS

The purpose of this Preliminary Amendment is to eliminate multiple dependent claims in order to avoid the additional fee. Applicants reserve the right to reintroduce claims to canceled combined subject matter.

Attached hereto is a marked-up version of the changes made to the claims by the current amendment. The attached pages are captioned **“Version With Markings to Show Changes Made”**.

Respectfully submitted,

Anthony J. Zelano, Reg. No. 27,969  
Attorney for Applicants  
MILLEN, WHITE, ZELANO & BRANIGAN, P.C.  
Arlington Courthouse Plaza 1  
2200 Clarendon Boulevard, Suite 1400  
Arlington, VA 22201  
Direct Dial: 703-812-5311  
Facsimile: 703-243-6410  
Email: zelano@mwzb.com

AJZ:kmo

Filed: 11 February 2002

**VERSION WITH MARKINGS TO SHOW CHANGES MADE**

3. (Amended) A compound according to claim 1 or 2 having the formula 2(2-nitro-1H-imidazol-1-yl)-N-(3,3,3-trifluoropropyl) acetamide ( $[^{18}\text{F}]\text{-EF2}$ ).
4. (Amended) A compound according to claim 1 or 2 having the formula 2(2-nitro-1H-imidazol-1-yl)-N-(2,2,3,3,3-pentafluoropropyl) acetamide ( $[^{18}\text{F}]\text{-EF5}$ ).
5. (Amended) A method for the synthesis of a compound according to ~~one of the~~ claims 1-4, comprising the step of coupling 2-(2-nitro-imidazol-1-yl) acetic acid with a  $[^{18}\text{F}]$ -labelled perfluoroalkyl amine derivative.
7. (Amended) A method for the synthesis of a compound according to ~~or one of the~~ claims 1-4 or the corresponding non-labelled form thereof, comprising the steps of:
  - a) adding a THF solution of 2 of Figure 7 to a suspension of PYBOP in THF followed by  $\text{Et}_3\text{N}$ ,
  - b) adding an amine 1 of Figure 7 and  $\text{Et}_3\text{N}$  to the solution obtained in step (a),
  - c) adding a catalytic amount to the solution obtained in step (b) of  $\text{pTsOH}$  and refluxing the solution,
  - d) cooling the solution obtained after step (c) at ambient temperature and adding a sodium bicarbonate solution,
  - e) extracting the product obtained after step (d) with ethyl acetate and drying and concentrating the product with ethyl acetate,
  - f) purifying the residue obtained after step (e) by column chromatography on silica gel,
  - g) removing traces of water by washing the product of step (f) with trifluoroacetic anhydride,
  - h) reacting said persulphurated derivative obtained from step (g) with a suitable labelled or non-labelled perfluorinating agent and a suitable oxidant resulting in a compound having a high yield of fluor atom incorporation,
  - i) deprotecting the nitrogen function, resulting in a perfluoroalkyl amine derivative, and
  - j) coupling the perfluoroalkyl amine derivative obtained in step (i) with an activated form of 2-(2-nitro-imidazol-1-yl) acetic acid, resulting in the  $[^{18}\text{F}]$ -labelled or non-

9. (Amended) A  $[^{18}\text{F}]$ -labelled compound obtainable by a method according to ~~one of the claims 5, 6, 7 or 8.~~

12. (Amended) A first intermediate compound according to claim 10-~~11~~ or ~~11~~, obtainable via steps a to g of the ~~—the~~ method as claimed in ~~claim 7~~ of the invention.

13. (Amended) A first intermediate compound according to claim 10-~~11~~ or ~~12~~, being ethyl 3-(N-phthalimido)-aminopropanedithioate, N-3,3,3-trifluoro-2-thioxopropyl) phthalimide, N-[2-(trifluoromethyl)-1,3-dithiolan-2-yl] methyl) phthalimide, methyl(or ethyl) 3-phthalimide-2,2-difluoropropanedithioate, N-[2,2-difluoro-3,3,3-tris(methylthio) propyl] phthalimide or N-[2,2-difluoro-3,3,3-tris(ethylthio)propyl] phthalimide.

16. (Amended) A second intermediate compound according to claim 14, ~~15 or 16~~ obtainable via steps a to h of the method of the invention.

17. (Amended) A second intermediate compound according to claim 14, being N-(3,3,3-trifluoropropyl)phthalimide.

20. (Amended) A third intermediate  $[^{18}\text{F}]$ -labelled compound obtainable via steps a to i of the ~~method as claimed in claim 7 or 8~~ of the invention.

21. (Amended) Use of compound according to ~~one of the~~ claims 1-4 as bioactive compound.

22. (Amended) A  $[^{18}\text{F}]$  labelled bioactive compound synthesized using as intermediates a first intermediate as claimed in ~~one of the claims 10-13~~, a second intermediate as claimed in ~~one of the claims 14-17~~ and a third intermediate as claimed in ~~one of the claims 10-13~~.

23. (Amended) A  $[^{18}\text{F}]$  labeled bioactive compound synthesized using as intermediates a first intermediate as claimed in one of the claims ~~10-13~~ 10.

24. (Amended) Method of perfuorination using as an intermediate a compound as claimed in one of the claims ~~10-13~~ 10.

26. (Amended) A method for the detection of tissue hypoxia in a patient comprising:  
- introducing an  $[^{18}\text{F}]$  labelled nitroimidazole compound of any of claims 1-to-4 into said patient,  
- imaging tissue hypoxia in said patient, and  
- quantifying tissue hypoxia in said patient.

28. (Amended) A method for the detection of tissue hypoxia in a tissue comprising:  
- introducing an  $[^{18}\text{F}]$  labelled nitroimidazole compound of any of claims 1-to-4 into a patient,  
- removing a tissue sample from said patient, and  
- analysing the emission in said tissue sample by autoradiograohy.

29. (Amended) A method for the detection of an  $[^{18}\text{F}]$  labelled bioactive compound in a patient comprising:  
- introducing an  $[^{18}\text{F}]$  labelled bioactive compound according to claim 1=4 into said patient,  
- imaging the presence of said  $[^{18}\text{F}]$  labelled bioactive compound in said patient, and  
- optionally, quantifying the presence of said  $[^{18}\text{F}]$  labelled bioactive compound in said patient.

30. (Amended) A method for the detection of  $[^{18}\text{F}]$  labelled bioactive compound in a tissue comprising:  
- introducing an  $[^{18}\text{F}]$  labelled bioactive compound of claim 1=4 into a patient,  
- taking a tissue sample from said patient, and  
- analysing the emission in said tissue sample by autoradiography.

PTO/PCT Rec'd 17 JUN 2002 # 4

**IN THE UNITED STATES DESIGNATED/ELECTED OFFICE**

International Application No. : PCT/EP00/04632  
International Filing Date : 22 MAY 2000  
Priority Date(s) Claimed : 11 AUGUST 1999  
Applicant(s) (DO/EO/US) : MARCHAND, Jacqueline, et al.

Title: METHODS FOR PREPARING PERFLUORINATED [<sup>18</sup> F]-RADIOLABELLED NITROIMIDAZOLE DERIVATIVES FOR CELLULAR HYPOXIA DETECTION

**SUPPLEMENTAL PRELIMINARY AMENDMENT**

Commissioner for Patents  
Washington, D.C. 20231

SIR:

Prior to calculating the national fee, and prior to examination in the National Phase of the above-identified International application, please amend as follows:

**IN THE CLAIMS:**

3. (Amended) A compound according to claim 1 having the formula 2(2-nitro-1H-imidazol-1-yl)-N-(3,3,3-trifluoropropyl) acetamide ([<sup>18</sup>F]-EF2).
4. (Amended) A compound according to claim 1 having the formula 2(2-nitro-1H-imidazol-1-yl)-N-(2,2,3,3,3-pentafluoropropyl) acetamide ([<sup>18</sup>F]-EF5).
5. (Amended) A method for the synthesis of a compound according to claim 1, comprising the step of coupling 2-(2-nitro-imidazol-1-yl) acetic acid with a [<sup>18</sup>F]-labeled perfluoroalkyl amine derivative.

REMARKS

The purpose of this Preliminary Amendment is to eliminate multiple dependent claims in order to avoid the additional fee. Applicants reserve the right to reintroduce claims to canceled combined subject matter.

Attached hereto is a marked-up version of the changes made to the claims by the current amendment. The attached pages are captioned **“Version With Markings to Show Changes Made”**.

Respectfully submitted,

Anthony J. Zelano, Reg. No. 27,969  
Attorney for Applicants  
MILLEN, WHITE, ZELANO & BRANIGAN, P.C.  
Arlington Courthouse Plaza 1  
2200 Clarendon Boulevard, Suite 1400  
Arlington, VA 22201  
Direct Dial: 703-812-5311  
Facsimile: 703-243-6410  
Email: zelano@mwbz.com

AJZ:kmo

7/prtr

## METHODS FOR PREPARING PERFLUORINATED [<sup>18</sup>F]-RADIOLABELLED NITROIMIDAZOLE DERIVATIVES FOR CELLULAR HYPOXIA DETECTION

The present invention relates to the field of chemical synthesis of 5 radiolabelled bioactive compounds for the detection of specific targets present in the tissues or cells of a patient and to the obtained [<sup>18</sup>F]-radiolabelled compounds and to the intermediates used in the method for their preparation.

In a first aspect the invention is related to [<sup>18</sup>F]-labelled perfluorinated compounds, in particular [<sup>18</sup>F]-EF3 and [<sup>18</sup>F]-EF5.

10 In a second aspect the invention is related to a method for the preparation of said labelled compounds and to their intermediates.

In a third aspect the invention is also related to the use of said [<sup>18</sup>F]-labelled compounds for cellular hypoxia detection.

15 More particularly, the present invention relates to the field of chemical synthesis of radiolabelled compounds to be used as indicators of tissue hypoxia. The present invention provides methods for preparing said type of compounds, as well as useful precursors in said synthesis and methods for preparing the same. The present invention also relates to methods of using these radiolabelled bioactive compounds for the detection of specific targets present in tissues of a 20 patient. More particularly the present invention relates to the detection of tissue hypoxia in a patient using said radiolabelled compounds.

25 Cellular hypoxia is a typical feature in various physiopathological processes as frequent as malignant tumor development, heart disease, stroke, diabetes and wound healing. In malignant tumors, experimental and clinical evidences have shown that the hypoxic fraction may influence the malignant phenotype, the growth rate and may reduce the sensitivity to ionizing radiation and chemotherapeutic agents. In head and neck lymph nodes, and in cervix carcinomas for example, tumour hypoxia is associated on an individual basis with a higher rate of local recurrence after radiotherapy. In stroke and heart infarct, it has been shown that

the severity of the tissue function impairment critically depends on the location and the amount of ischemic tissue.

In this framework, accurate determination of the magnitude of tissue hypoxia has always been a focus of intensive research. Such information is of great value as a prognostic factor of the severity of the disease, and as a tool to select for alternative therapies and to monitor the response to therapeutic interventions. In oncology, recent development in microelectrode techniques has permitted to measure the oxygen partial pressure ( $PO_2$ ) in experimental as well as clinical tumors. This technique has greatly contributed to the current knowledge on the influence of hypoxia in tumor physiopathology and response to treatment. Such a technique however has important limitations. The sensitivity of the method is far from being optimal in the range of  $PO_2$  values ( $<10$  mm Hg) of interest in oncology. It lacks specificity as it is also very much influenced by the amount of tissue necrosis around the microelectrode. Besides, it is an invasive and time consuming technique that will never be spread out in a routine clinical environment. In stroke and heart disease, there is no method to directly measure tissue hypoxia which can thus only be inferred from indirect measurements of tissue metabolism and vascularisation.

Tumor hypoxia is detected using hypoxia-binding chemical markers. These markers are nitroheterocyclic compounds which exhibit a particular metabolism under hypoxic cellular conditions, and hence can covalently bind to intracellular macromolecules (e.g. proteins, RNA, lipids and DNA). These reduced moieties trapped into hypoxic cells, can be detected by immunofluorescence on tissue section or by flow cytometry using for both techniques specific antibodies. Tagged with an appropriate radioactive isotope, these reduced moieties could also be detected by nuclear medicine techniques. Misonidazole is the prototype of hypoxia-binding chemical markers. More recently, a tri- and pentafluorinated nitroimidazole derivates, designated EF3 and EF5, respectively, have been synthesized (US patent No. 5,540,908 in name of Koch). In comparison with misonidazole, these 2 compounds have several advantages. Both compounds

have a more specific binding to hypoxic cells, and the binding does not depend on the intracellular level of reductase systems. In addition, fluorochrome-conjugated specific antibodies have been generated for both EF3 and EF5. Oxygen-dependent binding have been reported in various experimental systems such as 5 EMT6 spheroids, EMT6 tumors and Morris 7777 rat tumors. EF5 has been very recently approved by American Authorities for human studies and a phase I trial is in progress in the USA. Although very sensitive and specific, determination of cellular hypoxia with EF5 or EF3 remains however invasive as its requires the use of tissue specimens.

10 The  $[^{18}\text{F}]$  monofluorination of bioactive compounds is known; usually, the syntheses make use of the classical nucleophilic displacement of a leaving group with  $[^{18}\text{F}]$  fluoride anion. In particular, the method has been applied to the preparation of  $[^{18}\text{F}]$ -fluoroethanidazole (1) and  $[^{18}\text{F}]$ -fluoromisonidazole (2), and  $[^{18}\text{F}]$ -fluoroerythronitromidazole (3), three members of the nitroimidazole family.

15 In organic synthesis, the direct and selective perfluorination (-  $\text{CF}_2$ , -  $\text{CF}_3$  and -  $\text{C}_2\text{F}_5$ ) remains a difficult problem because the classical nucleophilic substitution strategy could not be efficiently applied (4). The preparation of perfluorinated molecules is increasingly problematical by way of simple fluorination techniques as the number of fluorine included in molecules increases; this results 20 from strong electronic repulsions between the fluorine atoms already present in a given molecule and the fluoride reagent which would enter into the molecule. Therefore, the construction of a  $\text{CF}_3$  group, from a carboxylic precursor, is usually carried out by the very strong and toxic reagent  $\text{SF}_4$  (4). Recently, an alternative 25 solution has been brought, making use of sulphurated precursors (ortho-trithioesters and dithioesters), halonium ions and an HF-reagent; however, this method is only applicable in the case of poorly functionalized aromatic compounds and conjugated compounds (5). In the aliphatic series, one precedent has been found, concerning the introduction of a  $\text{CF}_2$  group into non-functionalized alkyl chains (6).

Concerning the  $[^{18}\text{F}]$ -labelling of a  $\text{CF}_3$  group, the substitution method from a  $\text{CF}_2\text{Br}$  precursor has been used for two specific applications in which the competition with an elimination reaction could not occur (7). The  $[^{18}\text{F}]$ -labelling of 5  $\text{CF}_2$  and  $\text{CF}_3$  group from non-functionalized aromatic and aliphatic persulphurated precursors has been recently described by our group (8).

As far as functionalized aliphatic precursors are concerned (for instance, aminoacid derivatives), no precedent has been found in the literature for the  $[^{18}\text{F}]$ -labelling of  $\text{CF}_2$ ,  $\text{CF}_3$  or  $\text{C}_2\text{F}_5$  groups; this is the subject of the present invention.

10 The present invention aims at developing and testing labelled bioactive compounds, more particularly  $[^{18}\text{F}]$ -EF3 and  $[^{18}\text{F}]$ -EF5 for *in vivo* detection of hypoxia. Such a method would permit measurements of both the hypoxic fraction and the distribution of hypoxia within an individual tissue or tumor. In comparison with the existing methods for measuring hypoxia (e.g., microelectrode, 15 immunofluorescence and/or flow cytometry to detect hypoxia-binding chemical markers), the PET detection is a non-invasive technique that would allow individual measurements in any tumors and tissues. In comparison with other nuclear medicine techniques (e.g. SPECT), the PET camera detection offers the advantage of a better spatial resolution and a much more accurate quantification of 20 the radioactivity. In comparison with other hypoxia-binding chemical markers,  $[^{18}\text{F}]$ -EF3 and  $[^{18}\text{F}]$ -EF5 would maintain both their superior specificity and sensitivity for hypoxic cells as observed for the unlabelled parent compounds. Such a technique could be easily combined with anatomic imaging modalities (e.g. CT Scanner and 25 MRI) allowing a better mapping of the distribution of hypoxia in a specific tissue/organ. In addition, the detection of hypoxia by the PET method could also be combined with other functional imaging techniques (e.g. fMRI, PET with other markers) investigating important physiological parameters such as tissue proliferation or metabolism. Such a combined approach should allow to non-invasively study intriguing physiopathological questions related to tumor

development and response to treatment, or to functional tissue defect after an ischemic injury. Important physiopathological questions related to tumor development and response to treatment, or to the understanding of functional tissue defect after an ischemic injury could be investigated by this nuclear 5 medicine technique.

Thus assessment of tissue hypoxia with  $[^{18}\text{F}]\text{-EF3}$  or  $[^{18}\text{F}]\text{-EF5}$  is likely to allow significant benefits to the management of cancer and other human diseases. The structures of EF3 and EF5 are shown in Figure 1 (9).

The present invention thus aims at methods for synthesizing perfluorinated 10 radiolabelled bioactive compounds which selectively react with a target present in patient cells.

The present invention concerns the preparation of original sulphur-containing precursors as a first intermediate allowing the direct radiolabelling of perfluoroalkyl groups (-CF<sub>3</sub>, -CF<sub>2</sub>-) by  $[^{18}\text{F}]$  on substrates equipped with nitrogen-containing functions. This first intermediate is defined in claims 10, 11, 12 and 13. 15

The present invention also concerns the  $[^{18}\text{F}]$ -labelled perfluorinated second intermediate as defined in claims 14, 15, 16 and 17 and the  $[^{18}\text{F}]$ -labelled perfluorinated third and last intermediate having the formula of a perfluoropropylamine as defined in claims 18, 19 and 20.

20 More particularly, the present invention aims at methods for synthesizing  $[^{18}\text{F}]$  labelled perfluorinated nitroimidazole derivatives, more particularly methods for synthesizing  $[^{18}\text{F}]$  labelled EF3 and EF5.

The present invention also aims at useful sulphur-containing precursors for 25 synthesizing said compounds and methods for preparing the same.

The present invention further relates to the different uses of said perfluorinated radiolabelled bioactive compounds, more particularly the different uses of  $[^{18}\text{F}]$  labelled nitroimidazole derivatives, and even more particularly the uses of  $[^{18}\text{F}]$  labelled EF3 and EF5.

According to a first aspect the invention relates to novel  $[^{18}\text{F}]$ -radiolabelled 30 compounds as worded in claims 1-4.

According to another aspect, the present invention relates to a first type of precursor compound which is an amino acid derivative which is N-protected by an imido group or a synthetically equivalent group and wherein the carboxyl function has been transformed into a dithioester function or a synthetically equivalent 5 persulphurated moiety.

Such persulphurated amino acid derivatives may be used to prepare perfluorinated alkylamine derivatives using a suitable perfluorinating agent and a suitable oxidant as described below.

Said persulphurated compound may be derived from any of the following 10 amino acids:  $\alpha$ -amino acids of the natural pool such as: glycine, alanine, valine, leucine, isoleucine, proline, phenylalanine, asparagine, glutamine, aspartate, glutamate, and bis-protected serine threonine, lysine, arginine, histidine;  $\alpha$ -amino acids of synthetic origin and derivatives thereof;  $\beta$ -amino acids such a 3-aminopropionic acid and derivatives thereof,  $\gamma$ -amino acids such as 4-aminobutyric 15 acid and derivatives thereof,  $\delta$ -amino acids such as 5-aminovaleric acid and derivatives thereof,  $\varepsilon$ -amino acids such as 6-aminocaproic and derivatives thereof and similarly, the  $\omega$ -amino acid derivatives.

Said imido group may be any imido group known in the art, such as for instance a phthalimido group.

20 Said first type of precursor compound is used for the synthesis of a second and third precursor compound as described below. Figure 2 in combination with Figure 4 describes a representative synthesis of a precursor derived from  $\beta$ -alanine. Ethyl 3-(N-phthalimido)aminopropanedithioate having the general formula of the endproduct (3) of the reaction scheme presented in Figure 7 or Figure 2 is 25 an example of a persulphurated beta-alanine derivative.

According to a preferred embodiment, the present invention relates to a method for preparing a compound of claims 1-4 as shown in Figure 7 and 8 comprising the following steps:

- a) adding a THF solution of 2 of Figure 7 to a suspension of PYBOP in THF followed by Et<sub>3</sub>N,
- b) adding an amine 1 of Figure 7 and Et<sub>3</sub>N to the solution obtained in step (a),
- 5 c) adding a catalytic amount to the solution obtained in step (b) of pTsOH and refluxing the solution,
- d) cooling the solution obtained after step (c) at ambient temperature and adding a sodium bicarbonate solution,
- 10 e) extracting the product obtained after step (d) with ethyl acetate and drying and concentrating the product with ethyl acetate,
- f) purifying the residue obtained after step (e) by column chromatography on silica gel,
- 15 g) removing traces of water by washing the product of step (f) with trifluoroacetic anhydride,
- h) reacting said persulphurated derivative obtained from step (g) with a suitable labelled or non-labelled perfluorinating agent and a suitable oxidant resulting in a compound having a high yield of fluor atom incorporation,
- i) deprotecting the nitrogen function, resulting in a perfluoroalkyl amine derivative, and
- 20 j) coupling the perfluoroalkyl amine derivative obtained in step (i) with an activated form of 2-(2-nitro-imidazol-1-yl) acetic acid, resulting in the [<sup>18</sup>F]-labelled or non-labelled perfluorinated-nitroaromatic compound.

Compound 3 as shown in Figure 7 is known as Ethyl-3-(N-phthalimido)aminopropanedithioate. Compound 1 and its synthesis have been described in Josse et al., 1999 (10). Preferably, said method is used to prepare namely N-(phthalimido)3,3,3-trifluoropropylamine having the general formula of the endproduct 4 of the reaction scheme presented in Figure 8 as described in Example 2.

Said first intermediate perfluorinated compound according to this embodiment of the present invention is used for the synthesis of a second

intermediate compound which is an amino synthon which can be incorporated in the synthesis of [<sup>18</sup>F] labelled target-bioactive compounds by using the classical methods of peptide coupling, or other coupling methods. Examples of suitable perfluorinating agents and suitable oxidants according to the present invention are 5 given in Figure 3. Details of the preparation process of the [<sup>18</sup>F] perfluorinating agents appear in the earlier publications (8).

According to a preferred embodiment, the present invention relates to a perfluorinated derivative compound obtainable by a reaction wherein hydrogen fluoride/pyridine complex (HF-Pyridine) is used as a perfluorinating agent and 1,3-10 dibromo-5,5-dimethylhydantoin (DBH) is used as an oxidant, resulting in a compound having a high yield of fluor atom incorporation. Said perfluorinated reagent and reaction product can contain [<sup>19</sup>F] or [<sup>18</sup>F].

According to another embodiment, the present invention also relates to mixtures of [<sup>19</sup>F] and [<sup>18</sup>F] labelled perfluorinated derivative compounds as defined 15 above.

The [<sup>18</sup>F] isotope is incorporated in such an amount that the specific radioactivity of the compound is comprised between 1 and 30 Ci/mmol, preferably between 1 and 20 Ci/mmol, preferably between 1 and 10 Ci/mmol.

According to an even more preferred embodiment, the present invention 20 relates to a compound having the formula of the endproduct 4 of the reaction as shown in Figure 8.

According to a preferred embodiment, the present invention relates to a perfluorinated derivative of the compound of claims 1-4 obtainable according to a reaction defined in any of claims 5-8.

According to another embodiment, the present invention relates to a final 25 precursor compound which can be incorporated into the synthesis of [<sup>18</sup>F] target-bioactive compounds and which is a perfluorinated derivative of the first precursor described above wherein the nitrogen function has been deprotected by refluxing into hydrazine solution, or by using other deprotection methods, resulting in a 30 perfluoroalkyl amine derivative.

According to another embodiment, the present invention relates to a mixture of the radiolabelled perfluorinated bioactive compound and the non-radioactive labelled bioactive compound as defined above.

Preferably said final precursor according to the present invention is described in Figure 4 and is the endproduct (5). Since no procedure presently exists for direct and selective perfluorination of N-functionalized aliphatic compounds, the present invention brings a significant advance in organic chemistry in general (unlabelled compounds), and in the [<sup>18</sup>F] radiolabelling of biologically active compounds in particular.

The method according to the present invention is flexible since [<sup>18</sup>F]-perfluorinated alkylamines can be used as building blocks in various total syntheses of pharmaceuticals. The method illustrated in the examples section can easily be expected to be extended to any other amino acid of interest.

According to a preferred embodiment, the present invention thus relates to an [<sup>18</sup>F] labelled bioactive compound synthesized using as a precursor a perfluorinated derivative.

According to a preferred embodiment, the present invention thus relates to the use of said perfluorinated derivative having the formula of the endproduct 5 of the reaction scheme as shown in Figure 4 for chemical synthesis of an [<sup>18</sup>F] labelled perfluorinated nitroimidazole having an incorporation of [<sup>18</sup>F] atoms in such an amount that the specific radioactivity of the compound is comprised between 1 and 10 Ci/mmol.

According to a preferred embodiment, said [<sup>18</sup>F] labelled perfluorinated nitroimidazole compound is [<sup>18</sup>F] labelled EF3 having a general formula as set out in Figure 1.

According to another preferred embodiment, said [<sup>18</sup>F] labelled perfluorinated nitroimidazole compound is [<sup>18</sup>F] labelled EF5 having a general formula as set out in Figure 1. [<sup>18</sup>F] labelled EF5 can be prepared by using an appropriate persulphurated precursor (see Figure 6 for potential precursor types).

The present invention also relates to a method for the detection of tissue hypoxia in a patient comprising:

introducing an [<sup>18</sup>F] labelled nitroimidazole compound as defined above into said patient,

5        imaging tissue hypoxia in said patient, and,  
          quantifying tissue hypoxia in said patient.

Said patient is preferably a mammal and more preferably a human. Preferred nitroimidazole compounds to be used according to this embodiment of the invention are [<sup>18</sup>F] labelled EF3 or [<sup>18</sup>F] labelled EF5.

10      Methods for detecting tissue hypoxia in patient tissue include, but are not limited to non-invasive imaging techniques, immunohistochemistry, immunofluorescence, autoradiography and flow cytometry. Imaging techniques include, but are not limited to positron emission tomography (PET). Generally, imaging techniques involve administering a compound with marker atoms which can be detected externally to the mammal. A compound of the invention is dissolved or dispersed in a pharmaceutically acceptable diluent, such as non-pyrogenic physiological saline, is administered to the patient preferably intravenously. After administration, time is allowed for metabolism (reduction) of the hypoxic marker and clearance of the non-metabolized compound. Tissue 15 hypoxia is then assayed using one or several of the methods described above. Non-invasive imaging techniques can indeed be combined with immunohistochemistry, immunofluorescence, autoradiography or flow cytometry on tissue specimen.

20      According to a preferred embodiment, the detection technique used in said method is positron emission tomography.

The present invention also relates to a method for the detection of tissue hypoxia in a tissue comprising:

introducing an [<sup>18</sup>F] labelled nitroimidazole compound as defined above into a patient,

25        removing a tissue sample from said patient; and,

analysing the emission in said tissue sample by autoradiography.

Said patient is preferably a mammal and more preferably a human. Preferred nitroimidazole compounds to be used according to this embodiment of the invention are [<sup>18</sup>F] labelled EF3 or [<sup>18</sup>F] labelled EF5.

5 Also here, a compound of the invention, is dissolved or dispersed in a pharmaceutically acceptable diluent, such as non-pyrogenic physiological saline, is administered to the patient preferably intravenously. After administration time is allowed for metabolism (reduction) of the hypoxic marker and clearance of the non-metabolized compound. A sample of for instance tumor tissue taken from the  
10 patient is then analyzed. Methods of obtaining tissue samples include any surgical and non-surgical technique known in the art. Surgical methods include, but are not limited to biopsy such as fine needle aspirate, core biopsy, dilation and curettage. According to another embodiment, the present invention relates to a method for the detection of [<sup>18</sup>F] labelled bioactive compound in a patient comprising:

15 a) introducing an [<sup>18</sup>F] labelled bioactive compound according to claims 1-4 into said patient,  
b) imaging the presence of said [<sup>18</sup>F] labelled bioactive compound in said patient,  
c) quantifying the presence of said [<sup>18</sup>F] labelled bioactive compound in said  
20 patient.

Alternatively, the present invention also relates to a method for the detection of [<sup>18</sup>F] labelled bioactive compound in a tissue comprising:

25 a) introducing an [<sup>18</sup>F] labelled perfluorinated nitroimidazole compound as defined above into a patient,  
b) taking a tissue sample from said patient, and,  
c) analysing the emission in said tissue sample by autoradiography.

Said patient is preferably a mammal and more preferably a human.

Preferred nitroimidazole compounds to be used according to this embodiment of the invention are [<sup>18</sup>F] labelled EF3 or [<sup>18</sup>F] labelled EF5.

The examples as set out below are purely illustrative of a representative synthesis according to the embodiments of the present invention and are by no way intended to limit the present invention as set out in detail above. The content of all references referred to in this text is incorporated by reference.

**ABBREVIATIONS**

EEDQ	N-Ethoxycarbonyl-2-ethoxy-1,2-dihydroquinoline
PYBOP	Benzotriazole-1-yl-oxy-tris-pyrrolidino-phosphonium-hexa- 5 fluorophosphate
THF	tetrahydrofuran
pTsOH	para-toluenesulfonic acid
Et <sub>3</sub> N	triethylamine
DBH	dibromodimethylhydantoin
10 PET	Positron Emission Tomography
MRI	Magnetic Resonance Imaging
fMRI	functional Magnetic Resonance Imaging
SPECT	Single Photon Emission Computed Tomography
TLC	Thin layer chromatography

**FIGURE LEGENDS**

Figure 1 describes the chemical structure of EF5 and EF3

5 Figure 2 describes a reaction scheme for the synthesis of beta-Alanine Ethyl Dithioester. A part of this reaction scheme was previously described in Josse et al., 1999 (10).

10 Figure 3 describes the structure of the different perfluorinating agents and oxidants to be used in the labelling process according to the present invention.

Figure 4 describes the reaction scheme to prepare an  $[^{18}\text{F}]$ -perfluoroalkyl amine derivative from the persulphurated first precursor obtained in Figure 2.

15 Figure 5 describes the synthesis of EF3. Radiolabelled EF3 is made by using  $[^{18}\text{F}]$  perfluoroalkyl amine derivate of Figure 4 as a precursor in the last reaction step. X = 2,3,5,6-tetrafluorophenoxy.

20 Figure 6 describes the different possible potential precursor types for the synthesis of EF5.

Figure 7 describes the reaction scheme for the synthesis of ethyl 3-(N-phthalimido)aminopropanedithioate as described in Example 1

25 Figure 8 describes the reaction scheme for the synthesis of N-(phthalimido)3,3,3-trifluoropropylamine as described in Example 2.

**EXAMPLES****Example 1: Synthesis of ethyl 3-(N-phthalimido)aminopropanedithioate**

5 A THF solution of 2 is added to a suspension of PYBOP in THF followed by Et<sub>3</sub>N; the mixture is stirred during 40 minutes at 20°C. Then, amine 1 (as the trifluoroacetate salt; (10) and Et<sub>3</sub>N are added, and the mixture is stirred during 3 h at 20°C. After this reaction time and the addition of a catalytic amount of pTsOH, the solution is refluxed overnight. After cooling at ambient temperature, a sodium 10 bicarbonate solution is added and the product is extracted with ethyl acetate. Drying (MgSO<sub>4</sub>) and concentration under reduced pressure gave crude 3. The residue is purified by column chromatography on silica gel (hexane/ethyl acetate 30:70). Last traces of water are removed by washing the product with trifluoroacetic anhydride. The total yield was 85%. A yellow solid product was 15 obtained. Spectral data : <sup>1</sup>H NMR (CDCl<sub>3</sub>, 200 MHz) δ 1.26 (t, 3H, J=7.3 Hz), 3.18 (q, 2H, J= 7.3 Hz), 3.37 (t, 2H, J=7 Hz), 4.14 (t, 2H, J= 7 Hz), 7.73 (m, 2H), 7.85 (m, 2H); <sup>13</sup>C NMR (CDCl<sub>3</sub>, 50 MHz) ppm 11.93, 30.70, 38.24, 49.13, 123.30, 131.99, 167.97, 233.00.

**20 Example 2: Synthesis of [<sup>18</sup>F]-labelled N-(phthalimido)3,3,3-trifluoropropylamine**

25 The [<sup>18</sup>O]-water solution of [<sup>18</sup>F]-hydrogen fluoride is neutralized by a small amount of aqueous potassium hydroxide. Water is removed by evaporation till dryness, under an argon flux to give the potassium salt ([<sup>18</sup>F]-KF). Then, addition of a first portion of a dichloromethane solution of HF-Pyridine provides the desired radiolabelling agent. DBH is added and the mixture cooled to -78°C before introducing 3. The solution is allowed to reach the ambient temperature and is stirred for 30 minutes. A second fraction of a dichloromethane solution of HF-Pyridine is added for completing the reaction within 30 minutes. The trifluoromethyl 30 amine 4 is recovered with a specific radioactivity comprised between 1 and 30

Ci/mmol, as measured by Radio-TLC (Radio-Thin Layer Chromatography).  $^{19}\text{F}$ -NMR (282 MHz)  $\delta$  - 66.2 (t,  $J$  = 10.5 Hz).

Example 3: Synthesis of  $[^{18}\text{F}]$ -labelled 3,3,3-trifluoropropylamine

5 N-(Phthalimido) 3,3,3-trifluoropropylamine 4 is dissolved in acetonitrile and hydrazine hydrate (2 : 1), and heated at 75°C. The free amine is distilled under a slow stream of argon. The product is identified by comparison of the retention time in gas chromatography with authentic material.

10

Example 4: Synthesis of  $[^{18}\text{F}]$ -EF3

15 The  $[^{18}\text{F}]$ -3,3,3-trifluoropropylamine, prepared from 15 mg of ethyl 3-(N-phthalimido) aminopropanedithioate, was distilled and condensed at 0°C in an acetonitrile solution of 2,3,5,6-tetrafluorophenyl 2-(2-nitro-imidazol-1-yl) acetate obtained according to Tewson (1) (30 mg/3 ml of CH<sub>3</sub>CN). The mixture was stirred for 30 min. at 20°C, then purified by chromatography on silica gel with ethyl acetate as eluent.  $[^{18}\text{F}]$ -EF3 was recovered in 63 % yield as assayed by radio - TLC.

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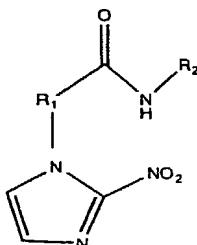
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## CLAIMS

1. A  $[^{18}\text{F}]$ -labelled perfluorinated-nitroaromatic compound having the formula:



5

wherein  $\text{R}_1$  is  $\text{CH}_2$  and  $\text{R}_2$  is an alkyl group having up to about 6 halogen atoms,  
10 wherein said alkyl group has the formula  $\text{CHXCX}_2\text{CY}_3$  where X is halogen or  
hydrogen and Y is fluorine.

2. A compound according to claim 1 having specific radioactivity of the compound  
comprised between 1 and 30 Ci/mmol, preferably between 1 and 20 Ci/mmol,  
15 preferably between 1 and 10 Ci/mmol.

3. A compound according to claim 1 or 2 having the formula 2-(2-nitro-1H-imidazol-1-yl)-N-(3,3,3-trifluoropropyl) acetamide ( $[^{18}\text{F}]\text{-EF3}$ ).

20 4. A compound according to claim 1 or 2 having the formula 2(2-nitro-1H-imidazol-1-yl)-N-(2,2,3,3,3-pentafluoropropyl) acetamide ( $[^{18}\text{F}]\text{-EF5}$ ).

25 5. A method for the synthesis of a compound according to one of the claims 1-4,  
comprising the step of coupling 2-(2-nitro-imidazol-1-yl) acetic acid with a  $[^{18}\text{F}]$ -labelled perfluoroalkyl amine derivative.

6. A method according to claim 5, wherein said coupling is a classical peptide coupling using a derivative of 2-(2-nitro-imidazol-1-yl) acetic acid in which the OH group of the carboxyl function has been replaced by a good leaving group.

5

7. A method for the synthesis of a compound according to one of the claims 1-4 or the corresponding non-labelled form thereof, comprising the steps of:

a) adding a THF solution of 2 of Figure 7 to a suspension of PYBOP in THF followed by Et<sub>3</sub>N,

10 b) adding an amine 1 of Figure 7 and Et<sub>3</sub>N to the solution obtained in step (a),

c) adding a catalytic amount to the solution obtained in step (b) of pTsOH and refluxing the solution,

d) cooling the solution obtained after step (c) at ambient temperature and adding a sodium bicarbonate solution,

15 e) extracting the product obtained after step (d) with ethyl acetate and drying and concentrating the product with ethyl acetate,

f) purifying the residue obtained after step (e) by column chromatography on silica gel,

20 g) removing traces of water by washing the product of step (f) with trifluoroacetic anhydride,

h) reacting said persulphurated derivative obtained from step (g) with a suitable labelled or non-labelled perfluorinating agent and a suitable oxidant resulting in a compound having a high yield of fluor atom incorporation,

i) deprotecting the nitrogen function, resulting in a perfluoroalkyl amine derivative, 25 and

j) coupling the perfluoroalkyl amine derivative obtained in step (i) with an activated form of 2-(2-nitro-imidazol-1-yl) acetic acid, resulting in the [<sup>18</sup>F]-labelled or non-labelled perfluorinated-nitroaromatic compound.

8. A method according to claim 7 wherein hydrogen fluoride/pyridine complex (HF-Pyridine) is used as a perfluorinating agent and 1,3-dibromo-5,5-dimethylhydantoin (DBH) is used as an oxidant resulting in a compound having a high yield of fluor atom incorporation.

5

9. A  $[^{18}\text{F}]$ -labelled compound obtainable by a method according to one of the claims 5, 6, 7 or 8.

10. A first intermediate compound having the general formula of an amino acid derivative which is N-protected by an imido group or a synthetically equivalent group and wherein the carboxyl function has been transformed into a dithioester function or a synthetically equivalent persulphurated moiety.

11. A first intermediate compound according to claim 10, wherein the imido group is a phthalimido group.

12. A first intermediate compound according to claim 10 or 11, obtainable via steps a to g of the method as claimed in claim 7.

20 13. A first intermediate compound according to claim 10, 11 or 12, being ethyl 3-(N-phthalimido)-aminopropanedithioate, N-(3,3,3-trifluoro-2-thioxopropyl) phthalimide, N-[[2-(trifluoromethyl)-1,3-dithiolan-2-yl] methyl] phthalimide, methyl (or ethyl) 3-phthalimide-2,2-difluoropropanedithioate, N-[2,2-difluoro-3,3,3-tris(methylthio) propyl] phthalimide or N-[2,2-difluoro-3,3,3-tris(ethylthio)propyl] phthalimide.

25 14. A second intermediate compound having the general formula of a  $[^{18}\text{F}]$ -labelled perfluorinated amino acid derivative which is N-protected by an imido group or a synthetically equivalent group.

15. A second intermediate compound according to claim 14, wherein the imido group is a phthalimido group.
16. A second intermediate compound according to claim 14 or 15, obtainable via 5 steps a to h of the method as claimed in claim 7 or 8.
17. A second intermediate compound according to claim 14, 15 or 16, being N-(3,3,3-trifluoropropyl)phthalimide.
- 10 18. A third intermediate compound having the general formula of a  $[^{18}\text{F}]$ -labelled perfluoroalkyl amine.
19. A third intermediate compound according to claim 18, being  $[^{18}\text{F}]$ -labelled 3,3,3-trifluoropropyl amine.
- 15 20. A third intermediate  $[^{18}\text{F}]$ -labelled compound obtainable via steps a to i of the method as claimed in claim 7 or 8.
21. Use of a compound according to one of the claims 1-4 as bioactive compound.
- 20 22. A  $[^{18}\text{F}]$  labelled bioactive compound synthesized using as intermediates a first intermediate as claimed in one of the claims 10-13, a second intermediate as claimed in one of the claims 14-17 and a third intermediate as claimed in one of the claims 10-13.
- 25 23. A  $[^{18}\text{F}]$  labelled bioactive compound synthesized using as intermediates a first intermediate as claimed in one of the claims 10-13.
24. Method of perfluorination using as an intermediate a compound as claimed in 30 one of the claims 10-13.

25. The compound of claim 22 which is an [<sup>18</sup>F] labelled perfluorinated nitroimidazole compound having an incorporation of [<sup>18</sup>F] atoms characterized by a specific radioactivity of the compound comprised between 1 and 30 Ci/mmol, 5 preferably between 1 and 20 Ci/mmol, preferably 1 and 10 Ci/mmol.

26. A method for the detection of tissue hypoxia in a patient comprising:

- introducing an [<sup>18</sup>F] labelled nitroimidazole compound of any of claims 1 to 4 into said patient,
- 10 - imaging tissue hypoxia in said patient, and
- quantifying tissue hypoxia in said patient.

27. A method according to claim 26 wherein the detection technique used in said method is positron emission tomography.

15

28. A method for the detection of tissue hypoxia in a tissue comprising:

- introducing an [<sup>18</sup>F] labelled nitroimidazole compound of any of claims 1 to 4 into a patient,
- removing a tissue sample from said patient, and
- 20 - analysing the emission in said tissue sample by autoradiography.

29. A method for the detection of an [<sup>18</sup>F] labelled bioactive compound in a patient comprising:

- introducing an [<sup>18</sup>F] labelled bioactive compound according to claim 1-4 into said patient,
- imaging the presence of said [<sup>18</sup>F] labelled bioactive compound in said patient, and
- optionally, quantifying the presence of said [<sup>18</sup>F] labelled bioactive compound in said patient.

30

30. A method for the detection of [<sup>18</sup>F] labelled bioactive compound in a tissue comprising:

- introducing an [<sup>18</sup>F] labelled bioactive compound of claim 1-4 into a patient,
- taking a tissue sample from said patient, and
- 5 - analysing the emission in said tissue sample by autoradiography.

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(74) Agent: BRANTS, Johan, Philippe, Emile; De Clercq,  
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Martens-Latem (BE).

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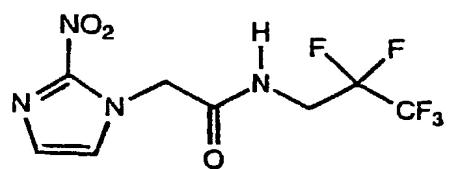
(71) Applicant (for all designated States except US): UNIVERSITE CATHOLIQUE DE LOUVAIN [BE/BE]; Place De L'Université 1, B-1348 Louvain-la-Neuve (BE).

(72) Inventors; and  
(75) Inventors/Applicants (for US only): MARCHAND, Jacqueline [BE/BE]; Rue Du Basson 48, B-6001 Marcinelle (BE). GREGOIRE, Vincent [BE/BE]; Rue Du Fond Marie Monseu 17, B-1330 Rixensart (BE).

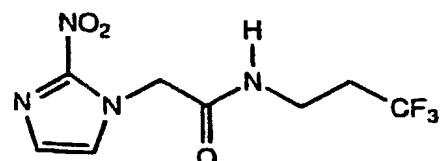
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(54) Title: METHODS FOR PREPARING PERFLUORINATED [<sup>18</sup>F]-RADIOLABELLED NITROIMIDAZOLE DERIVATIVES FOR CELLULAR HYPOXIA DETECTION

(57) Abstract: The present invention relates to chemical synthesis of radiolabelled perfluorinated bioactive compounds. More particularly, the present invention relates to radiolabelled compounds to be used as indicators for tissue hypoxia. More particularly, the present invention relates to the synthesis and the use of [<sup>18</sup>F] labelled perfluorinated nitroimidazole compounds having an incorporation of [<sup>18</sup>F] atoms characterized by a specific radioactivity of the compound comprised between 1 and 30 Ci/mmol, preferably between 1 and 20 Ci/mmol, preferably 1 and 10 Ci/mmol. More particularly to [<sup>18</sup>F] labelled EF3 or [<sup>18</sup>F] labelled EF5. The present invention also relates to a method for the detection of tissue hypoxia in a patient comprising introducing an [<sup>18</sup>F] labelled nitroimidazole compound into said patient, imaging tissue hypoxia in said patient, and, quantifying tissue hypoxia in said patient.



**EF5**



EF3

Figure 1

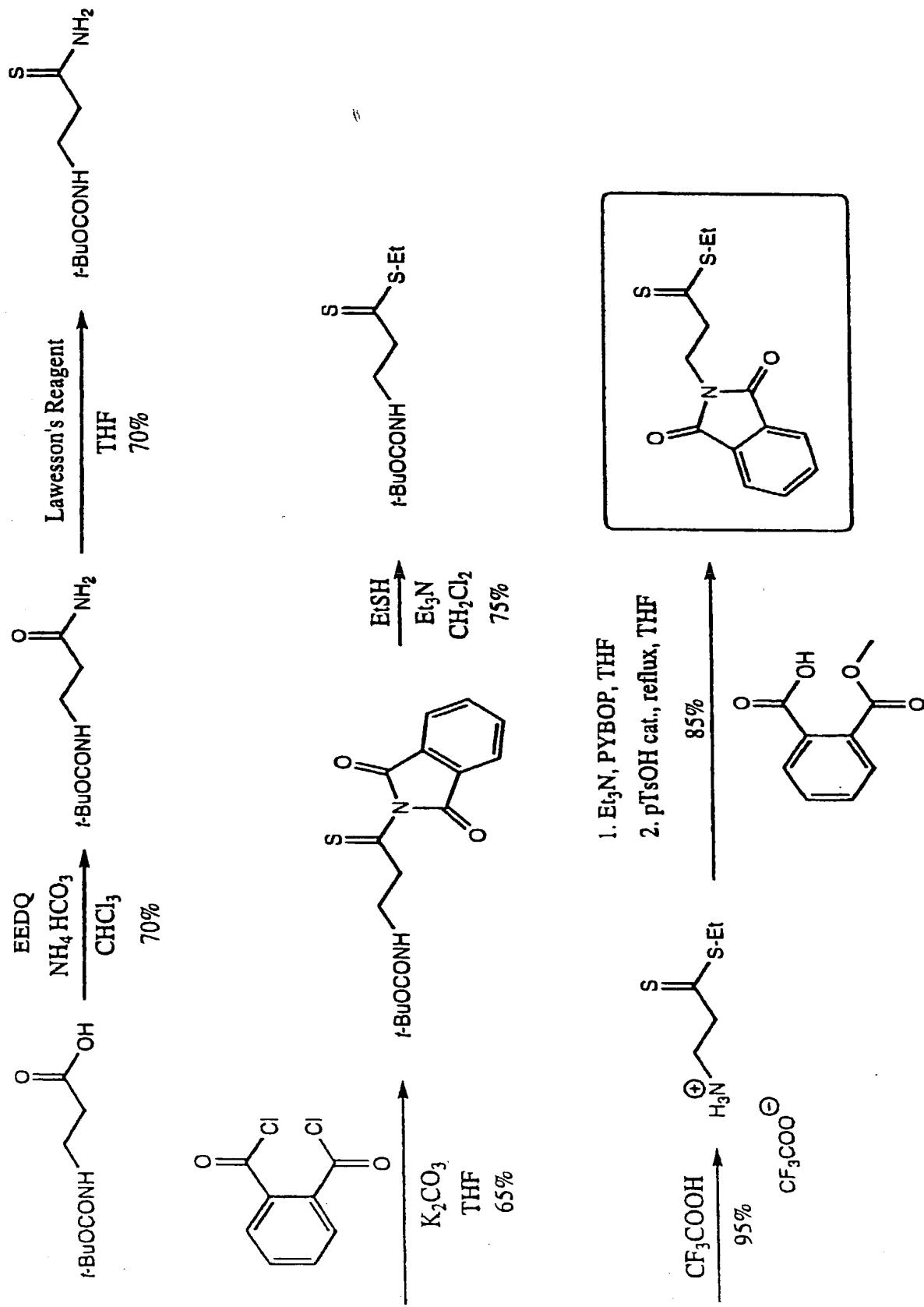
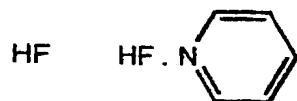
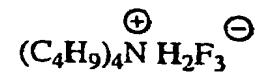
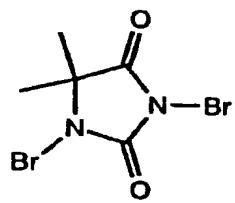
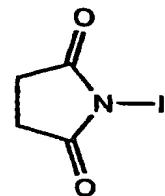


Figure 2

Pertluorinating agents

70%      30%

**HF-Pyridine**Oxidants**DBH****NIS**Figure 3

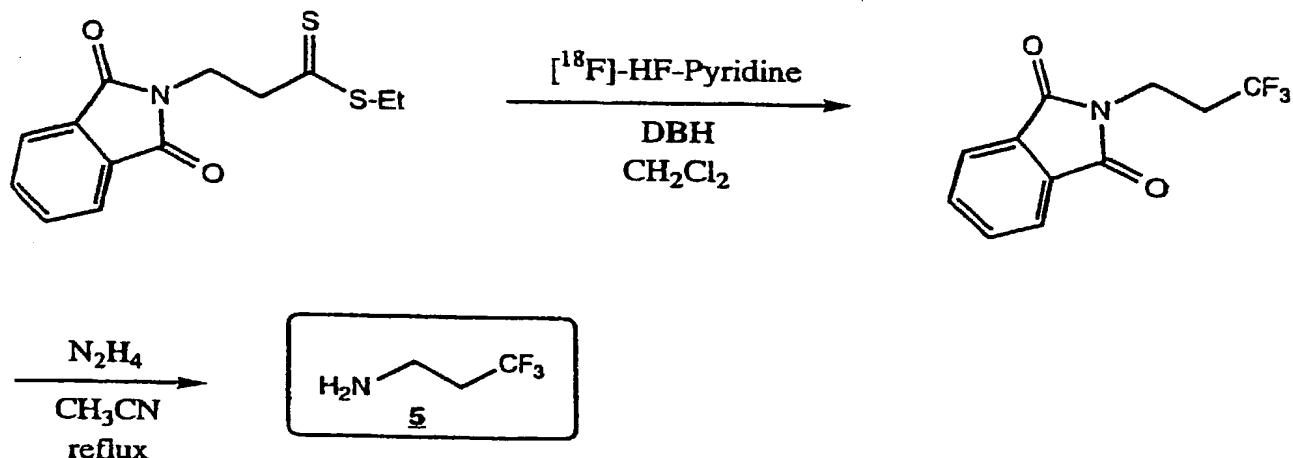
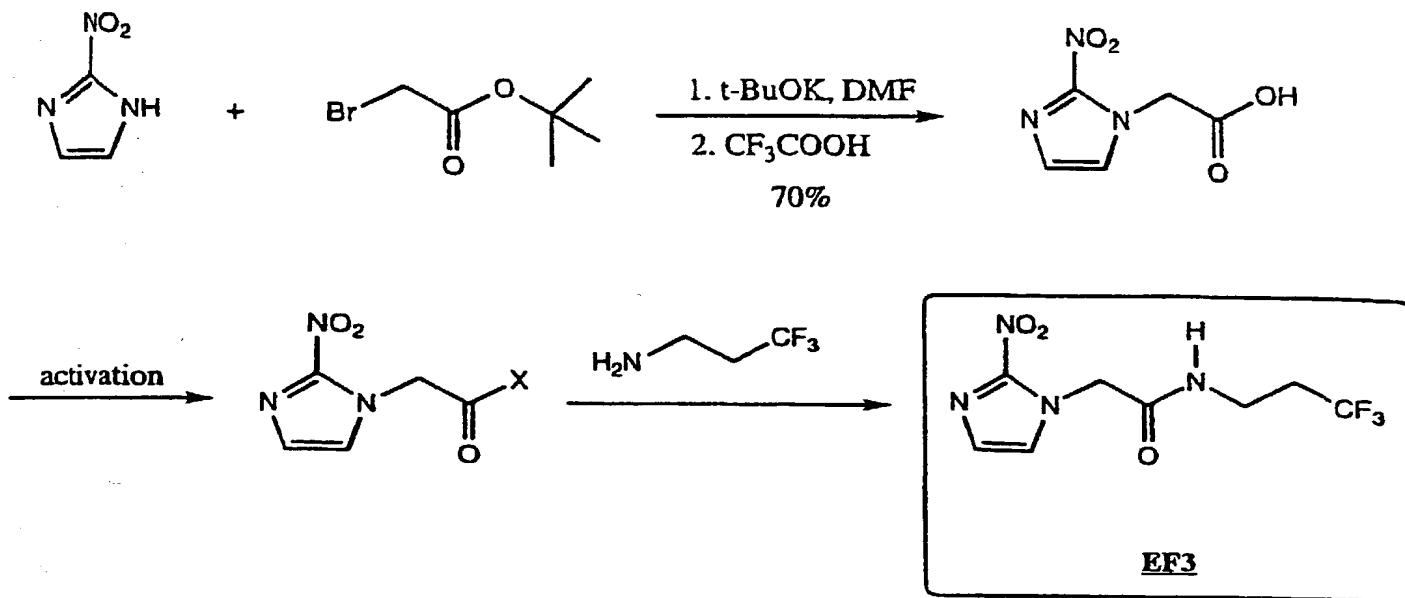


Figure 4

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*Figure 5*

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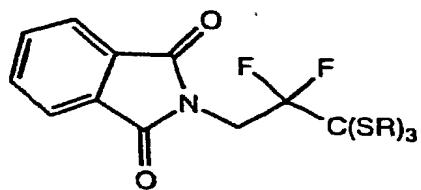
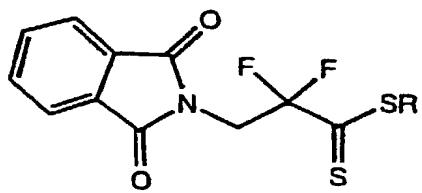
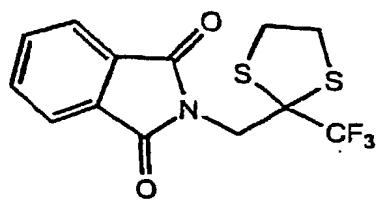
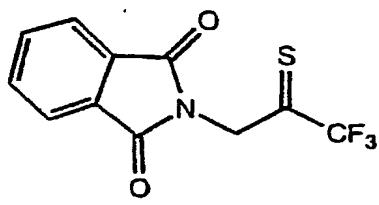
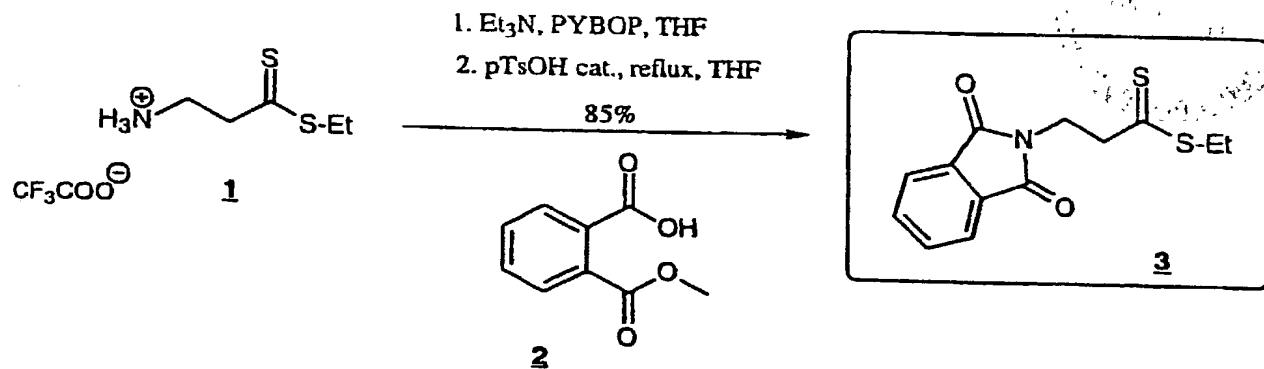
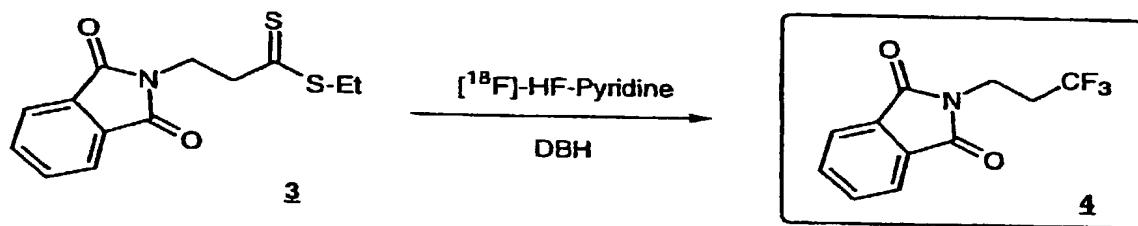


Figure 6

Figure 7Figure 8

## DECLARATION FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**METHODS FOR PREPARING PERFLUORINATED [<sup>18</sup>F]-RADIOLABELLED NITROIMIDAZOLE DERIVATIVES FOR CELLULAR HYPOXIA DETECTION**

the specification of which

is attached hereto

was filed on 22 MAY 2000 as United States Application Number or PCT International Application Number PCT/EP00/04632 and (if applicable) was amended on \_\_\_\_\_

I hereby authorize our attorneys to insert the serial number assigned to this application.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR §1.56.

I hereby claim foreign priority benefits under 35 U.S.C. §119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

**PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 USC §119**

APPLICATION NO.	COUNTRY	DAY/MONTH/YEAR FILED	PRIORITY CLAIMED
99870172.6	EP	11 AUGUST 1999	YES

I hereby claim the benefit under 35 U.S.C. §119(e) of any United States provisional application(s) listed below.

**PROVISIONAL APPLICATION(S) UNDER 35 U.S.C. §119(e)**

APPLICATION NUMBER	FILING DATE

I hereby claim the benefit under 35 U.S.C. §120 of any United States application, or §365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. §112.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR §1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

**PRIOR U.S./PCT INTERNATIONAL APPLICATION(S) DESIGNATED FOR BENEFIT UNDER 37 U.S.C. §120**

APPLICATION NO.	FILING DATE	STATUS — PATENTED, PENDING, ABANDONED

I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith: I. William Millen (19,544); John L. White (17,746); Anthony J. Zelano (27,969); Alan E.J. Branigan (20,565); John R. Moses (24,983); Harry B. Shubin (32,004); Brion P. Heaney (32,542); Richard J. Traverso (30,595); John A. Sopp (33,103); Richard M. Lebovitz (37,067); John H. Thomas (33,460); Catherine M. Joyce (40,668); Nancy J. Axelrod (44,014); James T. Moore (35,619); James E. Ruland (37,432); Jennifer J. Branigan (40,921) and Robert E. McCarthy (46,044)

## Declaration for Patent Application (Continued)

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full Name of sole or first inventor (given name, family name)

Jacqueline MARCHAND

Signature

Date

Residence

Marcinelle, Belgium

Citizenship

Belgium

Post Office Address Rue Du Basson 48 B-6001 Marcinelle, Belgium

Full Name of additional joint inventor (given name, family name)

Vincent GREGOIRE

Signature

Date

Residence

Rixensart, Belgium

Citizenship

Belgium

Post Office Address Rue Du Fond Marie Monseau 17 B-1330 Rixensart, Belgium

Full Name of additional joint inventor (given name, family name)

Signature

Date

Residence

Citizenship

Post Office Address

Full Name of additional joint inventor (given name, family name)

Signature

Date

Residence

Citizenship

Post Office Address

Full Name of additional joint inventor (given name, family name)

Signature

Date

Residence

Citizenship

Post Office Address

Additional joint inventors are named on separately numbered sheets attached hereto.